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A NEW THEORY OF OPTICS, AS REGARDS REFRACTION OF DENSE MEDIA, AND VISION.

BY ALEXANDER WATT,
APOTHECARY AND DRUGGIST.

Tempus omnia revelat.

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TO HIS GRACE

THE DUKE OF MANCHESTER,

&c. &c. &c.

MY LORD DUKE,

I HAVE been induced to dedicate this Work to your Grace, from a lively sense of the benefits derived from your Grace's administration, with which I am impressed, in common with the other inhabitants of this Island.

The auspicious appointment of your Grace to the Government of this Colony, was one of the many instances of the paternal anxiety of the best of Kings for the welfare of his subjects, who will ever cherish his memory with the most affectionate regard.

With the most grateful acknowledgments for your Grace's condescension in permitting this dedication,

I have the honour to subscribe myself,

MY LORD DUKE,

Your Grace's most devoted and obedient humble Servant,

THE AUTHOR.

PREFACE.

On perusing the existing doctrine upon the subject of Optics, as regards refraction of dense media, and vision, having been struck with some inconsistencies, in the explanations of those phenomena, with the results of experiments I had previously made in their elucidation, I have presumed to submit my ideas to the world in the following pages, in the hope of drawing the attention of the scientific world to the misconceptions and errors which have crept into it.

The figures given in illustration of the phenomenon of vision, and which are

borne out by the accompanying explanations, make it appear as if the images of objects are delivered by points of concentration of different pencils of rays of light upon the retina, and allow no refractive power to the cornea, and little or none to the chrystalline humour, notwithstanding their surfaces have very considerable convexities.

I am, therefore, in hopes I shall be able to shew that the convexities of the cornea and chrystalline humour, are very essential agents in the production of vision, and, although produced by the principle of the Camera Obscura, as is justly supposed, that its operation is entirely different from that which has hitherto been ascribed to it.

Having had neither time nor opportu-

nity to make experiments in the Camera Obscura, I am aware that some minor inaccuracies may be found in the following work; but as the disadvantages attendant upon a residence, which affords but few opportunities of scientific investigation, may continue to operate, I have preferred, rather than allow, the principles therein developed to lie dormant, to throw myself upon the liberal criticism of the public.

Kingston, Jamaica,
July 3d, 1824.

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INTRODUCTION.

Being desirous to furnish the reader with a comprehensive view of those branches of the science of Optics of which I propose to treat in the following pages, I shall begin with a brief history of the early discoveries which have been made in, and opinions entertained and advanced to the world upon them.

* "The first treatise of any note written on the subject of Optics was by the celebrated Astronomer Claudius Ptolomœus, who lived about the middle of the second century. The treatise is lost, but, from the accounts of others, we find that he treated of astronomical refractions.

"Though refraction in general has been ob-

* Encyclopœdia Britannica.

served very early, it is possible that it might not have occurred to any philosopher much before his time, that the light of the sun, moon, and stars must undergo a similar refraction, in consequence of falling obliquely upon the gross atmosphere that surrounds the earth, and that they must, by that means, be turned out of their rectilinear course, so as to cause the luminaries to appear brighter in the Heavens than they would otherwise do. The first astronomers were not aware that the intervals between stars appear less near the horizon than near the meridian; and, on this account, they have been much embarrassed in their observations.

"This philosopher also advances a very sensible hypothesis to account for the remarkably greater apparent size of the sun and moon when seen near the horizon. The mind, he says, judges of the size of objects by means of a preconceived idea of their distance from us; and this distance is fancied to be greater when a number of objects are interposed between the eye and the body we are viewing; which is the case when we see the heavenly bodies near the horizon. In his almagest, however, he ascribes this appearance to a refraction of the rays by vapours, which actually enlarge the angle under which the luminaries appear; *just as the angle is enlarged by which an object is seen from under water.*

" In the writings of Roger Bacon, whose genius, perhaps, equalled that of his great namesake Lord Virulam, we find the first distinct account of the magnifying power of glasses; and it is not improbable that what he wrote upon this subject gave rise to that most useful invention of spectacles. For he says, that, if an object be applied close to the base of the larger segment of a sphere of glass, it will appear magnified. He also treats of the appearance of an object through a globe, and says that he was the first who observed the refraction of rays in it.

" In 1270, Vitellio, a native of Poland, published a treatise of Optics, containing all that was valuable in Alhazen, and digested in a much more intelligible and methodical manner. He observes, that light is always lost by refraction, in consequence of which the objects seen by refracted light always appear less luminous; but he does not pretend to estimate the quantity of this loss. He reduced into a table the result of his experiments on the refractive powers of air, water, and glass, corresponding to different angles of incidence. In his account of the horizontal moon, he agrees exactly with Alhazen: Observing that in the horizon she seems to touch the earth, and appears much more distant from us than in the zenith,* on account of

* This is a manifest error, for all objects as they appear larger appear also nearer.

the intermediate space containing a greater variety of objects upon the visible surface of the earth. He ascribes the twinkling of the stars to the motion of the air in which the light is refracted; and to illustrate this hypothesis, he observes that they twinkle still more when received in water put in motion. He also shews that refraction is necessary as well as reflection to form the rainbow, because the body which the rays fall upon is a transparent substance, at the surface of which one part of the light is always reflected and another refracted. But he seems to consider refraction as serving only to condense the light, and thereby enabling it to make a stronger impression upon the eye. This writer also makes some ingenious attempts to explain refraction, or to ascertain the law of it. He also considers the foci of glass spheres, and the apparent size of objects seen through them, though upon these subjects he is not at all exact. *It is sufficient, indeed, to shew the state of knowledge, or rather ignorance, at that time, to observe that both Vitellio and his master Alhazen endeavour to account for objects appearing larger when they are seen under water, by the circular figure of its surface, since, being fluid, it conforms to the figure of the earth.*

" From this time to that of the revival of learning in Europe, we have no farther treatise on the subject of refractions, or indeed on any other part of optics. One of the first who dis-

tinguished himself in this way was Maurolycus, teacher of Mathematics at Messina. In a treatise *de lumine et umbra,* published 1575, he demonstrates that the chrystalline humour of the eye is a lens that collects the rays of light, issuing from objects, and throws them upon the retina, where is the focus of each pencil. From this principle he discovered why some people were short sighted, and others long-sighted, and why the former are relieved by concave, and the other by convex, glasses.

" About the same time that Maurolycus made such advances towards the discovery of the nature of visions, Joannes Baptiste Porta of Naples discovered the Camera Obscura, which throws still more light on the same subject. His house was constantly resorted to by all the ingenious persons at Naples, whom he formed into what he called ' An Academy of Secrets,' each member being obliged to contribute something that was not generally known, and might be useful. By this means he was furnished with materials for his ' Magia Naturalis' which contains the account of the Camera Obscura, the first edition of which was published, as he informs us, when he was not quite 15 years old. He also gave the first hint of the Magic Lantern, which Kircher afterwards followed and improved. His experiments with the Camera Obscura convinced him that vision is performed by the intromission of something into the eye,

and not by visual rays proceeding from the eye, as had been formerly imagined; and he was the first who fully satisfied himself and others on the subject. Indeed the resemblance between experiments with the Camera Obscura, and the manner in which vision is performed in the eye, was too striking to escape the observation of a less ingenious person. But when he says that the eye is a Camera Obscura, and the pupil the hole in the window-shutter, he was so far mistaken as to suppose that it was the chrystalline humour that corresponds to the wall which receives the images;* nor was it discovered till the year 1604 that this office is performed by the retina. He makes a variety of just observatious concerning vision; and particularly explains several cases in which we imagine things to be without the eye, when the appearances are occasioned by some affection of the eye itself, or some motion within the eye. He observes also, that, in certain circumstances, vision will be assisted by convex or concave glasses; and he seems also to have made some small advances towards the discovery of Telescopes. He takes notice that a round and flat surface plunged into water will appear hollow *as well as magnified to an eye* perpendicu-

* He was so far right as shall be shewn, when I come to that part of my subject; for the first representation *does take place* upon the front surface of the chrystalline humour.

larly over it; and he very well explains, by a figure, the manner in which it is done."

I shall now explain that branch of the science of optics, a knowledge of which I conceive is necessary to the full comprehension of my subjects; this branch is

REFLECTION OF LIGHT.

*" It is evident that, in order to thedue and regular reflection of light, that is, that the reflected rays should not be dispersed and scattered one from another, there ought to be no rasures or unevenness in the reflecting surface large enough to bear a sensible proportion to the magnitude of a ray of light; because, if the surface abounds with such, the reflected rays will rather be scattered like a parcel of pebbles thrown upon a rough pavement, than reflected with that regularity with which light is observed to be from a well polished surface.

" Now those surfaces which, to our senses, appear smooth and well polished, are far from being so, for to polish is no other than to grind off the larger eminences and protuberances of the metal with the rough and sharp particles of sand, emery, or putty, which must, of necessity, leave behind them an infinity of rasures and scratches, which, though inconsiderable with regard to the former roughness, and too

* Encyclopœdia Britannica.

minute to be discerned by us, must, nevertheless, bear a large proportion to, if not vastly exceed, the magnitude of the particles of light.

"Every visible body emits or reflects inconceivably small particles of matter from each point of its surface, which issue from it continually (not unlike sparks from a coal) in straight lines and in all directions. These particles entering the eye, and striking upon the retina (a nerve expanded on the back part of the eye to receive these impulses) excite in our minds the idea of light, and, as they differ in substance, density, velocity, or magnitude, they produce in us the ideas of different colours.

"That these particles proceed from every point of the surface of a visible body, and in all directions, is clear from hence, *viz.* because, wherever a spectator is placed with regard to the body, every point of that part of the surface which is turned towards him, is visible to him. That they proceed from the body in right lines, we are assured, because just so many and no more will be intercepted in their passage to any place, by an interposed object, as that object ought to intercept supposing them to come in such lines: In whatever direction, therefore, a person may be situated there will be points in the surfaces of objects which will reflect the rays of light upon the cornea, and the reason glass is less perceptible to vision than other substanes, would seem to be, that

its surface being so smooth is less calculated to reflect than transmit the light, unless it forms an angle with the incident rays; this transmission of light accounts for objects, which are covered with glass, such as prints, appearing brighter although the glass is not perceivable."

It will, therefore, be evident, that, as rays of light are reciprocally reflected from each surrounding object upon another, rays must impinge upon all objects, situated upon our earth in every direction, and it must, consequently, be equally evident, that as the equally innumerable inequalities in the surfaces of objects must produce as innumerable planes of larger dimensions than the minute rays of light impinging upon them, rays of light must be reflected from the surfaces of objects, in every direction, andmake them visible in whatever situation the spectator may be situated in front of those surfaces.

"When a ray of light falls upon any body, however transparent, the whole of it never passes through the body, but some part is always reflected or driven back from it; and it is by this reflected light that all bodies which have no light of their own, become visible to us.

"The fundamental law of reflection of light is that, in all cases the angle of reflection is equal to the angle of incidence, this is found by experiment to be the case. The axiom, therefore, holds good in every case of reflection, whether it be from plane surfaces or spherical

ones, and that whether they are convex or concave; and hence the seven following propositions relating to the reflection of light from plane and spherical surfaces may be deduced.

"I. Rays of light reflected from a plane surface have the same degree of inclination to one another that their respective incident ones have. For the angle of reflection of each ray being equal to that of its incident one, it is evident that each reflected ray will have the same degree of inclination to that portion of the surface from whence it is reflected that its incident one has, but it is here supposed, that all those portions of surface, from whence the rays are reflected, are situated in the same plane, consequently the reflected rays will have the same degree of inclination to each other that their incident ones have, from whatever part of the surface they are reflected.

"II. Parallel rays reflected from a concave surface are rendered converging. To illustrate this, let AF, CD, EB (fig. 1) represent three parallel rays falling upon the concave surface FB, whose centre is C. To the points F and B draw the lines CF, CB; these being drawn from the centre will be perpendicular to the surface at those points. The incident ray CD, also passing through the centre will be perpendicular to the surface, and therefore will return, after reflection, in the same line; but the oblique rays AF, EB, will be reflected into the

lines FM, BM, situated on the contrary side of their respective perpendiculars CF, CB; they will, therefore, proceed converging, after reflection, towards some point as M in the line CD.

"III. Converging rays, falling on the same surface, are made to converge more. For, (every thing remaining in the figure as above explained) let GF, HB, be the incident rays. Now, because these rays have larger angles of incidence than the parallel ones AF and EB in the foregoing case, their angles of reflection will also be larger than those of the others, they will, therefore, converge, after reflection, suppose in the lines FN, BN, having their points of concourse N farther from the point C than M, that to which the parallel rays AF and EB converged to in the foregoing case, and their precise degree of convergency will be greater than that wherein they converged.

"IV. Diverging rays, falling upon the same surface, are, after reflection, parallel, diverging, or converging. If they diverge from the focus of parallel rays, they then become parallel, if from a point nearer to the surface than that, they will diverge, but in a less degree than before reflection; if from a point between that and the centre, they will converge after reflection, and that to some point on the contrary side of the centre, but situated farther from it than the point from which they diverged. If the incident rays diverge from a point beyond the

centre, the reflected ones will converge to one on the other side of it, but nearer to it than the point they diverged from; and if they diverge from the centre, they will be reflected thither again.

"1. Let them diverge in the lines MF, MB proceeding from M, the focus of parallel rays; then, as the parallel rays AF and EB, were reflected into the lines FM and BM (by Prop. II.) these rays will now, on the contrary, be reflected into them.

"2. Let them diverge from N, a point nearer to the surface than the focus of parallel rays, they will then be reflected into the diverging lines FG and BH, which the incident rays GF and HB described that were shewn to be reflected into them in the foregoing proposition; but the degree wherein they diverge will be less than that wherein they diverge before reflection.

"3. Let them proceed diverging from X, a point between the focus of parallel rays and the centre; they then make less angles of incidence than the rays MF and MB, which became parallel by reflection; they will, consequently, have less angles of reflection, and proceed, therefore, converging towards some point as Y; whicb point will always fall on the contrary side of the centre, because a reflected ray always falls on the contrary side of the perpendicular with respect to that on which its incident one

falls; and, of consequence, it will be farther distant from the centre than X.

"4. If the incident ones diverge from Y, they will, after reflection, converge to X; those which were the incident rays in the former case being reflected ones in this. And lastly

"5. If the incident rays proceed from the centre, they fall in with their respective perpendiculars; and, for that reason, are reflected thither again.

"V. Parallel rays reflected from a convex surface are rendered diverging. For, let AB, GD, EF, (fig. 2.) be three parallel rays, falling upon the convex surface BF, whose centre of convenity is C, and, let one of them, *viz.* GD, be perpendicular to the surface. Through B, D, and F, the points of reflection, draw the lines CV, CG, and CT; which, because they pass through the centre, will be perpendicular to the surface at these points. The incident ray GD, being perpendicular to the surface, will return, after reflection, in the same line, but the oblique ones AB and EF in the lines BK and FL, situated on the contrary side of their respective perpendiculars BV and FT. They will, therefore, diverge after reflection, as from some point M in the line GD produced; and this point will be in the middle between D and C.

"VI. Diverging rays reflected from the like surface are rendered more diverging. For, (every thing remaining in the figure as above), let

GB, GF, be the incident rays. These having larger angles of incidence than the parallel ones AB and EF in the preceding case, their angles of reflection will also be larger than theirs: They will, therefore, diverge after reflection, suppose in the lines BP and FQ, as from some point N, farther from C than the point M; and the degree wherein they will diverge, will be greater than that wherein they diverged before reflection.

" VII. Converging rays reflected from the like surface, are parallel, converging, or diverging. If they tend towards the focus of parallel rays, they then become parallel, if to a point nearer the surface than that, they converge, but in a less degree than before reflection; if to a point between that and the centre they will diverge after reflection, as from some point on the contrary side of the centre, but situated farther from it than the point they converged to. If the incident rays converge to a point beyond the centre, the reflected ones will diverge as from one on the contrary side of it; but nearer to it than the point to which the incident ones converged; and, if the incident rays converge towards the centre, the reflected ones will proceed as from thence.

" 1. Let them converge in the lines KB, and LF, tending towards M, the focus of parallel rays; then as the parallel rays AB EF, were reflected into the lines BK and FL (by Prop. V.)

those rays will now, on the contrary, be reflected into them.

"2. Let them converge in the lines PB, QF, tending towards N, a point nearer the surface than the focus of parallel rays, they will then be reflected into the converging lines BG and FG, in which the rays GB GF proceeded, that were shewn to be reflected into them by the last proposition: but the degree wherein they will converge will be less than that wherein they converged before reflection.

"3. Let them converge in the lines RB and SF, proceeding towards X, a point between the focus of parallel rays and the centre, their angles of incidence will, therefore, be less; on which account they must necessarily diverge, suppose in the lines BH and FI from some point, as Y; which point (by Prop. IV.) will fall on the contrary side of the centre with respect to X, and will be farther from it than that.

"4. If the incident rays tend towards Y, the reflected ones will diuerge as from X; those which were the incident ones in one case being the reflected ones in the other.

"5. Lastly, if the incident rays converge towards the centre, they fall in with their respective perpendiculars; on which account they proceed after reflection as from the centre."

I shall now give the existing doctrine on the subject of refraction, which branch I propose

treating of, so as to enable the reader to judge for himself.

"The phenomena of refraction are explained by an attractive power in the medium through which light passes in the following manner: All bodies being endowed with an attractive force, which is extended to some distance beyond their surfaces; when a ray of light passes out of a rarer into a denser medium (if this latter has a greater attractive force than the former as is commonly the case) the ray, just before its entrance, will begin to be attracted towards the denser medium; and this attraction will continue to act upon it till some time after it has entered the medium; and, therefore, if a ray approaches a denser medium in a direction perpendicular to its surface, its velocity will be continually accelerated during its passage through the space in which that attraction exerts itself; and, therefore, after it has passed that space, it will move on till it arrives at the opposite side of the medium with a greater degree of velocity than it had before it entered; *so that in this case its velocity only will be altered;* whereas if a ray enters a denser medium obliquely, it will not only have its velocity augmented thereby, but its direction will become less oblique to the surface, just as when a stone is thrown downwards obliquely from a precipice, it falls to the surface of the ground in a direction nearer to a perpendicular one, than that with which it was thrown

from the hand. From hence we see a ray of light, in passing out of a rarer into a denser medium, is refracted towards the perpendicular; that is, supposing a line drawn perpendicularly to the surface of the medium through the point where the ray enters, and extended both ways, the ray in passing through the surface is refracted or bent towards the perpendicular line; or which is the same thing, the line it describes by its motion, after it has passed through the surface, makes a less angle with the perpendicular, than the line it described before. All which may be illustrated in the following manner:

" Let us suppose first, that the ray passes out of a vacuum into a denser medinm—A, B, C, D, (fig. 3.) and that the attractive force of each particle in the medium is extended from its respective centre to a distance equal to that which is between the lines AB, EF, or AB, GH; and let KL be the path described by a ray of light in its progress towards the denser medium.—This ıay, when it arrives at L, will enter the attractive forces of those particles which lie in AB, the surface of the denser medium, and will, therefore, cease to proceed any longer in the right line KLM, but will be diverted from its course by being attracted towards the line AB, and will begin to describe the course LN, passing through the surface AB in the same new direction as OQ; thereby making a less angle with a line as PR, drawn perpendicularly through

the point N, than it would have done had it proceeded in its first direction KLM.

"Farther: Whereas we have supposed the attractive force of each particle to be extended through a space equal to the distance between AB and EF, it is evident that the ray, after it has entered the surface, will still be attracted downwards till it has arrived at the line EF; for, till that time, there will not be too many particles above it, which will attract it upwards as below that will attract it downwards. So that, after it has entered the surface at N, in the direction OQ, it will not proceed in that direction, but will continue to describe a curve, as NS; after which it will proceed straight on towards the opposite side of the medium, being attracted equally every way; and therefore will at last proceed in the direction XST, still nearer the perpendicular PB, than before.

"Now, if we suppose ABZY not to be a vacuum, but a rarer medium than the other, the case will still be the same; but the ray will not be so much refracted from its rectilinear course, because the attraction of the particles of the upper medium being in a contrary direction to that of the attraction of those in the lower one, the attraction of the denser medium will, in some measure, be destroyed by that of the rarer.

"On the contrary, when a ray passes out of a denser into a rarer medium, if its direction be perpendicular to the surface of the medium, it

will only lose somewhat of its velocity, in passing through the spaces of attraction of that medium (that is the space wherein it is attracted more one way than it is another). If its direction be oblique, it will continually recede from the perpendicular during its passage, and by that means have its obliquity increased, just as a stone thrown up obliquely from the surface of the earth, increases its obliquity all the time it rises. Thus supposing the ray TS passing out of the denser medium A, B, C, D, into the rarer ABZY, when it arrives at S it will begin to be attracted downwards, and so will describe the curve SNL and then proceed in the right line LK; making a larger angle with the perpendicular PR than the line TSX in which it proceeded during its passage through the other medium."

The foregoing doctrine is further exemplified, as follows:

"A ray of light AB, falling obliquely on a plane surface, will go out of the glass in the same direction, but not in the same straight line, for, in touching the glass it will be refracted in the line BC, and in leaving the glass it will be refracted in the line CD.*

* To avoid prolixity I have to observe here, that a ray as KL (fig. 4.) impinging upon a convex surface, in the same angle as AB, will pass through the medium in the direction LM, but if upon a plane surface, it will continue in the same direction through the medium.

"Further: An object placed within a medium, terminated by a plane surface on that side which is next the eye, if the medium be denser than that in which the eye (as we shall always suppose to be, unless where the contrary is expressed) appears nearer the surface of the medium than it is. Thus, if A (fig. 5.) be a point of an object placed within the medium BCDE, and A b, A c, be two rays proceeding from thence, these rays passing out of a denser into a rarer medium will be refracted from their respective perpendiculars b d, c e, and will enter the eye at H, suppose in the direction b, f, c, g. Let then these lines be produced back till they meet in F; this will be the apparent place of the point A, and because the refracted rays b, f, c, g, will diverge more than the incident ones A b, A c, it will be nearer to the points b and c than the point A; and as the same is true of each point in the object, the whole will appear to an eye at H nearer the surface BC than it is.*

"From hence it is, that when one end of a straight stick is put under water, and the stick is held in an oblique position, it appears bent at the surface of the water, *viz.* because each point that is under water appears nearer the surface, and consequently higher than it is.

* I have to observe, that if the surface of the medium had no convexity the ray would proceed to the eye in the line h (fig. 5.)

"From hence likewise it is that an object at the bottom of a vessel may be seen, when the vessel is filled with water, though it be so placed, with respect to the eye, that it cannot be seen when the vessel is empty.

"To explain this—let ABCD (fig. 6.) represent a vessel, and let E be an object lying at the bottom of it. This object, when the vessel is empty will not be seen by an eye at F, because HB, the upper part of the vessel, will obstruct the ray EH; but when it is filled with water to the height GH, the ray EK being refracted at the surface of the water into the line KF, the eye at F shall see the object by means of that."

A NEW THEORY

OF

OPTICS,

&c. &c.

REFRACTION.

IT was my original intention to have confined myself to the subject of vision, but, on making some experiments of the refractions of water and glass, so as to be able to give some introductory explanation of those phenomena, having detected some errors in the existing doctrine upon that subject, it became indispensable to explain them before I could attain the object I had in view.

It is asserted in the existing doctrine that a ray of light, * "just before its entrance, will begin to be attracted towards the denser medium, and this attraction will continue to act upon it till some time after it has entered the medium, and, therefore, if a ray approaches a denser medium in a direction perpendicular to its surface, its velocity will be continually accelerated during its passage through the space in which that attraction exerts itself; and, therefore, after it has passed that space, it will move on, till it arrives at the opposite side of the medium with a greater degree of velocity than it had before it entered. So that in this case *its velocity only* will be altered."

This, although I do not admit, I do not mean to combat here, is not the only effect produced, for the most superficial observation will prove that the ray is not only shortened but magnified; this I shall illustrate by a similar figure as that given in the existing doctrine, differing only where the experiment, if made, will shew that the facts differ.

Let ABCD (fig. 7.) be the dense medium as water, and let PR be the ray entering it perpendicularly, it will, immediately on entering the surface, appear shortened and magnified as P r; the bottom of the vessel will also appear raised towards the surface as c, d.

It is likewise asserted, that a ray of light

* Encyclopædia Britannica.

which *" enters a denser medium obliquely will not only have its velocity augmented thereby, but its direction will become less oblique to the surface, just as when a stone is thrown downwards from a precipice, it falls to the surface of the ground in a direction nearer to a perpendicular one, that is, supposing a line drawn perpendicularly to the surface of the medium, through the point where the ray enters and extended both ways, the ray in passing through the surface is refracted or bent towards the perpendicular line; or, which is the same thing, the line which it describes, by its motion, after it has passed through the surface, makes a less angle with the perpendicular, than the line it described before."

Now, instead of its making a less angle with the perpendicular, it will be found that it makes a larger angle with it. To illustrate this, let KN (fig. 7.) be a ray of light directed obliquely towards the surface of the dense medium; the ray, immediately on entering the surface, instead of being bent down, will be bent up in a new direction, as if it was broke at the surface, and form a larger angle with the perpendicular PR, and a less angle with the surface than before it entered: It will also appear both shortened and magnified as NT.

As no experiments can be made, in this way, with rays of light, otherwise than by means of

* Encyclopædia Britannica.

material substances, (the results of which, as light is material, is completely applicable) I shall instance the effect produced upon a piece of straight stick when inserted into water.

If a piece of straight stick be inserted into water, in the direction KN, it will assume the same proportionate appearance in the water as NT to KN; and, if a piece be inserted to the bottom of the water perpendicularly, it will assume the same proportionate appearance as N r to PN; and the bottom of the vessel CD, where the stick touches, will appear raised with it as c d.

It is therefore evident that, as the point of the stick which is inserted in the water is magnified, and thrown up towards the surface, the different points in it, and rays reflected from them, are also magnified, and thrown up nearer the surface.

From hence it is, that an object at the bottom of a vessel may be seen when the vessel is filled with water, though it be so placed with respect to the eye that it cannot be seen when the vessel is empty, and not agreeable to the existing doctrine laid down in the Introduction as shall be shewn. In short, it is self-evident, that if the rays of light were attracted down towards the perpendicular, after the water is poured in, that the image of the object would be depressed, and still farther from a right line, over the edge of the vessel, to the eye.

To illustrate this, let A (fig. 8.) represent a vessel; B the object on the bottom of it, at the edge farthest from the eye; D the rays which would proceed from the object to the eye, if the vessel was empty, but which cannot reach the eye in consequence of the intervention of the side of the vessel; F the water. As the water is poured in, the bottom of the vessel and the object will appear to rise into sight over the edge of the vessel, until the whole of the object comes into view, whence emanate the rays E, which convey the representation of the object over the edge of the vessel to the eye.

It will, no doubt, be immediately seen, that the above explanation and annexed figure represent the fact, and that fig. 4 and its explanation do not, and consequently cannot, lead to a reasonable solution of the cause; the object, at the same time that it appears raised nearer the eye, appears also triflingly magnified.

Now, instead of looking at the object over the edge of the vessel through the surface of the water, let it be viewed through the side of the vessel, in an angle lower than the surface of the water, and it will be found to be magnified fourfold its natural size; this effect seems to be produced in the direction of the convexity of the vessel; it is to be understood that the object, in this experiment, is at the farthest side of the bottom of the vessel; it is also to be observed that the size of the object alters agree-

able to the distance it may be at from the near convex surface of the vessel which produces the effect; that is, if it is placed near it, the size is much diminished, although still magnified, and as it is moved farther off from it, the size increases in a corresponding ratio, until it is moved to the farthest extremity of the bottom of the vessel, when the appearance is produced which has been already explained.

It will likewise be found, that the bottom of the vessel and the object will be thrown forward nearer the eye, towards the side of the vessel it is viewed through.

In illustration, let A (fig. 9.) represent a glass vessel or tumbler; C the farthest part of the bottom of the vessel and the object, as they are seen before the water is poured in; D the farthest part of the bottom of the vessel and the object as they are really seen in consequence of refraction after the water has been poured in. Let an experiment be made with a tumbler or other glass vessel, whose sides are completely flat, making its form a perfect square, and it will be found that the object will not be magnified in the smallest degree, nor the appearance of its real situation on the bottom of the vessel altered, if the bottom and sides of the vessel be truly flat.

In illustration, let A (fig. 10.) be the vessel, and B the object; the latter represents the ap-

pearance of the object which will be produced by the experiment, that is, it will have the same appearance as it had before the water was poured in.

I have not been able to make an experiment by a globular vessel, therefore cannot state the effects actually produced by it, but I have no hesitation in saying, that I have no doubt that effects will be produced corresponding to its convexity in all directions, and that those effects will magnify the appearance of the object in every direction, and bring it apparently nearer the eye.

It will, however, be found, that the object will have the same appearance in all the foregoing differently formed vessels, (as is exemplified in fig. 8.) when viewed through the surface of the water.

If, therefore, the foregoing various experiments seem to indicate that the influencing causes are the greater, less, or no convexity of the vessels in which the experiments may be made, and which I think cannot, for a moment, be doubted, is it not reasonable to conclude that the effects produced upon the appearance of an object when immersed in, and viewed through water, is caused by a trifling convexity of its surface? I am the more inclined to think so, as the effect is completely analagous to that produced by convex surfaces; this is proved by

the effects produced upon the object on being moved, progressively, from the side of the vessel next the eye, until it touches the farthest part of the bottom as explained p. 27–28, which are in strict conformity with those produced by moving a convex lens, nearer or farther from an object which is viewed through it.

The foregoing effects may, I conceive, be easily accounted for, by ascribing them to the well known effects produced upon the appearances of objects by the angles under which they are viewed.

In order to simplify this, therefore, as much as I can, I shall instance the effects produced, to the naked eye, upon the appearances of an object at different distances, and, at the same time, endeavour to explain the cause of those effects.

Let AB (fig. 11.) be an object at different distances from the eye as 1, 2, 3,; let a a, b b, c c, be rays proceeding from them respectively to the eye; it is evident that the rays proceed to and enter the eye at very different angles according to the distance at which it is from the eye; the angle of those from 1, being greatest and of those from 3, the least; consequently the object appears in size in exact proportion to those angles, and also at proportionate distances; 1 appearing largest and nearest, and 3 farthest off and smallest.

Let us look at an object with a convex lens

in such a manner that we can see it double, that is, let one eye look through the lens and the other naked at an object, when one of the images will appear larger and nearer than the other; (in proportion to the convexity of the lens) then close the eye which looks through the lens, and it will be found that the nearest magnified image will disappear; this, therefore, proves that objects seen through transparent dense media, with convex surfaces, are brought apparently nearer, and are magnified.

Having endeavoured to establish the probability that the refraction of the rays of light reflected from an object immersed in water, is occasioned by the convex surface of the water, and not by any innate refractive quality in the water itself, as a dense medium, I shall now endeavour to explain the cause which I conceive produces this convexity.

The principle which produces this effect, is, I conceive the same which, at its first creation formed, and has ever since retained, this terraqueous globe of a spherical form.

This principle, the existence of which I have endeavoured to prove in my Theory of Physical Astronomy (to which I refer the reader for a full and, I hope, comprehensive and satisfactory explanation) I conceive to be the circumambient dense atmosphere constantly rushing in upon the surface of our globe to recover the equilibrium, which has been disturbed by the heat

which has prevailed near its surface ever since its creation.

The only Philosopher, either ancient or modern, who ever hinted that the magnifying quality of water was owing to its surface being of a circular figure, conformable to the figure of the earth, was Vitellio, but as he gave no reason, that was considered satisfactory, why he thought so, his idea was exploded, as only shewing the ignorance of that period (see Introduction, page 4,) and still stands condemned, although deserving a better fate.

I am of the same opinion with that most ingenious man, although I am not indebted to him for it, as I was not aware of his doctrine when I formed it; this assertion will be believed when my work upon Physical Astronomy shall have been read, when it will be found evidently consequential.

It is this agency, which I have just explained, which keeps the ocean, as well as the earth of this globe of a spherical form, which makes all portions of water assume surfaces of corresponding convexities with that of the earth.

I conceive it is this agency which makes the surfaces of all fused bodies, such as glass, and all the metals, assume a like convexity, although recognizable only in glass, in consequence of its transparency; and I conceive the various degrees of refraction observable in glass differently compounded, and in glass made at different

times although composed of the same proportions of the same ingredients, may be occasioned by the greater or less degree of heat with which they may have been made, and the different capacities, the different compounds may have possessed for retaining that heat, consequently preserving them a longer or shorter period in a state susceptible of the action of the dense atmosphere; water, however, whilst it remains fluid, is only subject to have this effect produced upon it in an equal degree.

I am, therefore, of opinion, that the effects produced upon the appearances of objects immersed in water are not the consequences of any refractive quality in water, but of the convexity of its surface.

In order, however, to make myself better understood, I shall explain how this effect is produced.

In my Theory of Physical Astronomy, before alluded to, I have endeavoured to prove that the light directed from the sun to the earth is refracted in a cone, and that, if its course had not been intercepted by the earth, it would have completed its apex, and formed one of those irradiations, which we call stars.

This, therefore, makes the radius of the rays of light directed from the sun to the earth equal to the distance of the stars from the sun; their angle of convergency must, therefore, be very trifling indeed; it is, in fact, so trifling,

that it is not observable in the shadow of the largest object on our earth, as no sensible difference can be detected betwixt the breadth of a shadow at its extremity and at the object.—The cone in which our globe is situated, I conceive, is not of greater diameter than the earth, and the caloric or heat is confined within that space, and near its surface; therefore, the exterior dense atmosphere, in constantly rushing in to recover the equilibrium, constitutes the agency I have already explained.

The surface of this terraqueous globe being, by the agency already explained, rendered much more convex than the surface of the sun which refracts the cone of rays of light directed to it, all water upon its surface, having the same convex surface, refracts the rays of light from the less convergency from the sun to the greater convergency of the radius of the earth's convexity.

Let A (fig. 12.) be the earth; c, c, the same object immersed in the water, and out of it; a, a, the rays which proceed from the object perpendicularly to the cornea; EE the rays which proceed from the object immersed in the water, in the angle of the convexity of the earth; F, F, rays which proceed again from them perpendicularly to the cornea of the eye.

It will, therefore, be evident, that the rays FF, proceeding to the eye in a wider angle than a a, will magnify the object, and make it appear

nearer, agreeable to the well known law in this case already explained.

The same cause magnifies the appearance of the sun, moon, and stars when they first appear in our horizon, and as they are descending below it.

Let A (fig. 13.) be the sun or moon; B the earth; C the earth's atmosphere; D the eye upon the surface of the earth; EE the rays in the angle of convergency from the sun; F the same rays refracted to the earth's centre; it is therefore evident, that the rays, after refraction, proceed to the eye in a wider angle than before they entered the earth's atmosphere, and consequently produce the magnified and nearer appearance of the sun, moon, &c.; this effect, however, gradually ceases with the cause, for this magnified appearance gradually lessens as the sun or moon ascends towards the zenith; may not this be occasioned by the influence of their heat in gradually dissipating that degree of density capable of producing refraction?*

* Is not this idea countenanced by the effects produced by the reflected light of the moon, which even dissipates the clouds?

THE REFRACTION OF GLASS.

Having given my ideas respecting the refraction of water and the earth's atmosphere, I shall now proceed to treat of the refraction of glass.

By corollary 5 to proposition 1, in the British Encyclopædia, it is advanced as follows:

"Hence if the semi-diameters of the surfaces of the glass be equal, its focal distance is equal to one of them; and is equal to the focal distance of a plano-convex lens or plano-concave glass, whose semi-diameter is as short again."

Let, therefore, C (fig. 14.) be the double convex lens, the semi-diameters of whose surfaces are equal as D; let E be a plano-convex lens, whose semi-diameter is as short again as F; their focal distances will be equal as D.*

In order to put the foregoing to the proof, I took the convexity of a plano-convex lens with wax, and struck the circle, of which its convexity formed a segment, and found that its focal distance was equal to the diameter of its circle; I likewise found that the focal distance of a double convex lens, the semi-diameter of whose surfaces were equal, was equal to the

* It will be observable here that, for the sake of distinction, I have called the focus the distance at which the rays, after divergency from the radiant point, deliver the image of objects.

semi-diameter of one of its surfaces; which are the same results as the foregoing figure explains.

This being the case, what becomes of the supposed innate refractive quality of glass, as independent of the convexity of its surface? The fact seems to be, that it does not alter the radius from that of the convexity of its surface; may not, therefore, a very reasonable doubt be entertained whether such an innate quality exists in glass?

The fact appears to be, that refractions are occasioned by the convexities of surfaces only; and that where the convexity has not, artificially, been made greater than the natural surfaces produced by the action of the atmosphere, the convexity of the surface of a small quantity of water (being that of the earth) or glass, which, in so small a surface, is so trifling as not to appear, has not been suspected, and that the effect thereby produced has, consequently, been ascribed to an innate refractive quality in the different transparent dense media.

It is necessary to observe, that the atmosphere of the earth becomes a dense medium in consequence of the absence of the rarifying principle, called caloric, or heat; this absence is occasioned by the descent of the sun in the evening, his rarifying influence having then ceased to operate upon our horizon; this being the case, the atmosphere of the earth becomes

condensed, so as to constitute a dense medium, capable of conveying the rays of light in the angle of the convexity of its surface, having its radius in the centre of the earth; this convexity is produced by the influence of the same principle which keeps our globe of a spherical form.

This doctrine, although not admitted as accounting for the refraction of water and other dense media, is supposed to cause that of the atmosphere, which is explained in the Encyclopædia Britannica as follows:

"In like manner an object situated in the horizon appears above its true place, upon account of the refraction of the rays which proceed from it, in their passage through the atmosphere of the earth. For, first, if the object be situated beyond the limits of the atmosphere, its rays, in entering it, will be refracted towards the perpendicular, that is, towards a line drawn from the object, where they enter to the centre of the earth, which is the centre of the atmosphere; and as they pass on they will be continually refracted in the same way, because they are all along entering *a denser part*, the centre of which convexity is still the same point; upon which account the line they describe will *be a curve bending downwards*, and therefore none of the rays that come from that object can enter an eye upon the surface of the earth, except what enter the atmosphere higher than they

need to do, if they could come in a right line from the object, consequently the object must appear above its proper place. Secondly, if the object be placed within the atmosphere, the case is still the same, for the rays which flow from it must continually enter a denser medium, whose centre is below the eye, and therefore, being refracted towards the centre, that is, *downwards*, as before, those which enter the eye must necessarily proceed as from some point above the object; wherefore the object will appear above its proper place.

" From hence it is that the sun, moon, and stars, appear above the horizon when they are just below it; and higher than they ought to do when they are above it; likewise distant hills, trees, &c. seem to be higher than they are."

The sun, moon, trees, &c. do not appear alone higher when the atmosphere is dense, but they appear equally magnified in every direction, under the refractive influence of the convex surface of that atmosphere; the very same effect is produced upon them, which is produced upon objects viewed through convex glasses; the real body of the sun, moon, &c. are exactly in the centre of their magnified representations.

The error seems evidently to have arisen out of the error already pointed out (fig. 7.) which I presume to think must have arisen from the following causes:

First. From its not having been discovered that refraction was produced by the convexity of the surface of the medium, which, when once produced at the surface, does not alter in degree, whilst the convexity of the surface remains the same.

Secondly. From having made an error in the figure explanatory of the doctrine, which is that of having made the oblique ray enter at the same place as the perpendicular does; for let the oblique ray enter on either side of the perpendicular, and the explanation becomes correct, *viz.* "From hence we see a ray of light in passing out of a rarer into a denser medium is refracted towards the perpendicular;" but not in the manner explained, for, instead of its forming a less angle with the perpendicular, it forms a larger one (see fig. 7.) wherein the oblique ray a, b, c represents the effect.

It becomes, therefore, a natural consequence that, were the sun, moon, &c. to remain stationary any time upon our horizon, their influence would expand the atmosphere until its density ceased, and the effect of that density with it.

VISION.

For my grounds of reasoning in my endeavours to explain my Theory of Vision, and deduce my conclusions as to the causes that produce that sense, I shall adopt the explanation of the structure of the eye given by Mrs. Bryan, as, being as much divested of technical phraseology as the subject can possibly admit, best suited to the comprehension of the general reader.

"The eye is placed in a bony cavity, called the orbit. its form is globular; within this globe are contained three different kinds of humours, inclosed in several distinct sorts of teguments or coats, in which blood vessels, nerves, and arteries are curiously interwoven.

"I shall first treat of the external advantages attendant on the mechanism of the eye, and its concomitant appendages.

"The inside of the orbit, which contains the eye, is lined with a lubricating and membraneous substance, which affords the eye a soft bed to perform its movements in, without injury to its delicate substance. Those arches of hair, called eye-brows and eye-lids, are not less useful than beautiful, for they defend the eyes from too strong a light, and prevent dust,* or other small substances, from falling into them, by being provided with muscles for the purpose

of projecting or drawing them down, so as to defend the eye from a glare of light, and from incumbent particles of dust.

"The eye-lids afford also a perfect and secure asylum for the eye when we sleep, or have occasion to guard against internal injury, when we are awake, and unfearing external annoyance, the eye-lids, by their motion, diffuse a fluid over the eye, which keeps it constantly moist and clear, by which alone it could answer the purposes of vision.

"The eye-lids join at their two extremities, and, that they may shut with greater exactness, and not fall into wrinkles when they are elevated, each edge is stiffened with a cartilaginous arch, which is bordered with hair; by the latter the contour of the eye-lids is softened, the eye protected from straggling motes, and the light moderated in its approach to the retina. The eye-lids also assist in these desirable effects, by excluding a superabundant quantity of light.

"The upper part of the orbit of the eye has a gland placed in it, which constantly furnishes sufficient moisture for keeping the part of the eye exposed to the air in a proper state of lubricity and pellucidity, and, that this purpose may be fully answered, without our attention to it, we shut the eye-lids or wink our eyes, without the concurrence of our will or reason.

"The corner of the eye, next the nose, is provided with a caruncle, for the purpose of

keeping that corner of the eye from being perfectly closed, that any tears, &c. may flow under the eye-lids, when we sleep, into two little holes, one of which is in each eye-lid near the corner, for carrying off any superfluous moisture.

"The eye is furnished with six muscles, which spread their tendons far over the eye, in order to effect a motion in every direction, excepting an oblique one towards the nose, which is aided by a particular auxiliary, the side of the eye next the nose not allowing room for a muscle, a small bone is placed on the side of the nose, with a hole in it, which serves as a pulley for the tendon of a muscle to pass through, by which an oblique direction of the eye is obtained.

"The eyes have a parallel or uniform motion, in which they always coincide, this is extraordinary to human reason, as the organs of the eyes are totally distinct,* having no communi-

* This appears to common reason to be a mistake, for the uniform motion of the eyes is evidently strictly mechanism, as may easily be proved, by shutting one eye, and placing the hand upon it, so that the motion of it can be felt, and then looking with the open eye in every direction, when an involuntary aud indeed evident coercive corresponding motion will be felt in the closed eye; may not this corresponding motion of the eyes be affected by means of a ligament connecting them from the inner side of the one to the other, or in some other manner, and which being cut, and, having consequently collapsed to each eye, not have been detected? In further proof, let any person squint artificially, and he will feel considerable pain produced by it, which I conceive would not be the case was the unison of the action of the eyes not a mechanical effect.

cation with each other, and yet they appear actuated by the same force or mechanism.

"The purpose supposed to be effected by this unison of action and direction, is that of seeing things single which are viewed double.*

"I shall give you Sir Isaac Newton's supposition respecting our seeing things single which are painted double, that is, the two images of the object painted on the retina, one in each eye, appearing but as one to the imagination.

"'The species of objects seen with both eyes, may unite where the optic nerves meet before they come into the brain, the fibres of both nerves uniting there, and, after unison, going thence into the brain, in the nerve which is on the right side of the head, and the fibres on the left side of both nerves uniting in the same place, and, after union, going into the brain in

* This no doubt occasions the double representations of objects on the retinas of the two eyes to reflect upon one representation on the sensorium, without which there would be a confusion of two representations from the different foci of the eyes, which would occasion indistinct vision: Is not this exemplified in the case of a person who squints, who, to obtain a correct view of objects, is obliged to turn his head on one side so as to view them with one eye, thereby to obtain a single and correct view of them.

Does not, therefore, the circumstance of a person's squinting being the effect of an early habit, in consequence of being held whilst a child too near objects, and thereby obliged to look at them within the axis of the eyes, suggest the idea that it is occasioned by the contraction of one or more ligaments and the extension of others?

the nerve which is on the left side of the head, and these two nerves meeting in the brain in such a manner that their fibres make but one species or picture, half of which is on the right side of the sensorium and comes from the right side of both eyes through the right side of both optic nerves to the place where the nerves meet, and from thence to the right side of the head into the brain; and the other half on the left side comes in the like manner from the left side of both eyes.

" 'The optic nerves of all animals which look the same way, as men, horses, dogs, &c. meet before they come into the brain, but the optic nerves of such animals as do not look the same way with both eyes, as fishes,* do not meet before they go into the brain.' "

"This conjecture appears reasonable, and may therefore be admitted; but the effect must, after all, be referred to the mind, as well as what causes that involuntary motion which produces the effect, or that motion which causes the image to be seen at all, for although, undoubtedly vision, or the appearance of objects, is occasioned by the pictures on the retina, yet the eye can see no part of itself. It is the mind that perceives and judges, the eye is only the medium,

* An idea strikes me here, that the reason why the eyes of fishes are flatter than those of all other animals, may be to counteract the refraction of water, already explained, which would otherwise make objects appear larger than they are.

or instrument, by which the idea is conveyed to the mind; and for the operations of the mind upon the body, or the body upon the mind, we are unable to account.

" Considering the eye merely as an instrument, we need not inquire why, when the pictures of objects are painted in it, in a reverse posture, our imagination perceives them upright, to solve which Anatomists have been unable, nor can they ever afford us a rational solution of a circumstance independent of the organization of the human body.* All our senses are aided by the mechanism of the organs created for their use, but their impressions are referable only to the spirit, the understanding, and, therefore, only definable by human comprehension.

" Having treated of the principal external parts of the eye, and the advantages procured by their nice adjustment, I shall venture to speak of its internal parts, which will be less digressive, as all the instruments used to aid astronomical investigation, have been constructed upon the principle of refraction, reflection, &c. effected by the various humours and coats of the eye, and therefore they will be better understood from a description of this grand original and its affections.

* This reasoning I can by no means subscribe to, for, if every one who has contributed to the advancement of the sciences, had been thus satisfied, we should not have acquired our present knowledge, although, possibly, still far short of what it may be.

"The globe of the eye consists of several coats containing three pellucid humours, which are so adjusted, that the rays proceeding from luminous objects, and admitted at the forepart of the eye, called the pupil, *are brought to a focus on the back part of it.*

"The outer coat, or sclerotica, (fig. 15. a.) is a hard substance, of a whitish colour, resembling parchment, the hinder part of which is very thick and is opaque, from whence it becomes gradually thinner as it approaches the part in the front of the eye, where the white terminates; the other part of this tegument is thin and transparent and projects a little, forming a segment of a smaller sphere.

"This part is called the cornea (b.) from its transparency; this quality of it is necessary for the admission of the light; this membrane is composed of several layers, and replenished with clear water and pellucid vessels.

"The second coat of the eye, or the choroides, (c.) is soft and tender, is composed of innumerable little vessels, and it adheres to the sclerotica; it is outwardly of a brown colour, and inwardly almost black; this tegument, like the sclerotica, is distinguished by two names, the forepart being called the uvea, and the hindpart the choroides.

"The forepart, or uvea d, d, commences where the cornea begins, i. e. at the edge of that dark part of the eye called the iris. It is attached to

the sclerotica by a narrow circular rim, from which part the choroides divides from the sclerotica, which part, from where it turns inwards, to the hole in its centre, called the pupil, is called the iris, which is composed of the dark colour of the choroides called the uvea, combined with the reflections of the light, occasioned by the puckering of the membrane on turning inwards.

"The pupil of the eye, e, has no determinate size, but depends on the action of the membrane which forms it, which either expands or contracts it, so as to accommodate the organ of sight to the strongest or weakest impressions of the particles of light, as thus, when the light is too intense, the pupil is contracted, to prevent the admission of too great a quantity of light, which would injure the sight, but when the light is weaker the pupil is enlarged, and thereby a greater quantity of the rays of light fall upon the retina, in order to render it, in both cases, duly active. The whole of the choroides is opaque, therefore, no light can enter the eye but what passes through the pupil.*

"The third and last membrane of the eye is called the retina, because it is spread like a net

* The uvea goes across the eye in a straight direction, and by preventing any light from penetrating, unless through the hole in its centre, called the pupil, forms the camera obscura of the eye.

over the back of the eye. It is a continuation of the optic nerve, and lines the inside of the choroides, and the concave side of it covers the surface of the vetreous humour, terminating where the choroides turns inwards, so that it contains the vetreous humour. On this membrane, within side the eye, that is, on its concave surface, are painted the image of objects.

" The coats contain the humours of the eye, one humour forms a solid substance, another is soft, and the other is perfectly liquid ; the humours are of such forms and transparency, as are best adapted for transmitting the rays of light, and placing them in positions favourable to distinct vision. They are all clear like pure water, possessing no essential colouring particles, therefore the colours exhibited by them must be derived from the impressions of the different particles of light.

" The most fluid of these humours is called aqueous, it fills the interstice between the cornea and the pupil, and also the space between the latter and the chrystalline humour ; its form is plano-convex, its quantity is so abundant that it swells out the fore part of the eye into the segment of a small sphere, it is not known from whence this humour is supplied, yet its source is so unfailing that, if the coat, which contains it, be wounded, so that the humour all flows out, if the eye is kept closed a proper time for the wound to heal, the fluid will be recruited.

"The second humour is called the chrystalline, (f) it is as transparent as the aqueous but less in quantity, and more dense, of the consistence of stiff jelly, its form is doubly convex, but the two parts are of different convexities, the most convex part is received into an equal concavity in the vitreous humour.

"The chrystalline is contained in a kind of case, the fore part of which is thick and elastic, the hind part thin and soft; this case is suspended in its place by a muscle, which, together with the chrystalline, divides the globe of the eye into two unequal portions, the smaller and foremost containing the aqueous humour, the larger and posterior the vitreous.

"The chrystalline humour has no visible communication with its case, for when it is opened the humour slips out.

"The vitreous (G) is the third and last humour of the eye, and appears like glass, it is neither so dense as the chrystalline, nor so liquid as the aqueous; it fills the greatest part of the globe of the eye, filling all the space between the sclerotica, from the insertion of the optic nerve to the chrystalline lens.

"The optic nerve passes out of the seat of the brain through a small hole in the bottom of the orbit of the eye, it enters the orbit of a form nearly globular, but compressed, and is inserted into the globe of the eye nearly in the middle, though not quite so, but rather higher and nearer to the nose."

EXISTING DOCTRINE ON VISION.

The ideas of all modern Anatomists and Opticians, have hitherto been, that the rays of light are reflected from the different points in the object in cones, or pencils, having their apexes in the points from whence they are reflected, upon the chrystalline humour, or lens, and that they are again converged by the chrystalline humour in different other cones, to apexes or foci, to the retina, upon which they are supposed to deliver the image of the object reversed in every part.

In illustration of this doctrine, the following explanation is given:

* " As every point of an object as A, B, C, (fig. 16.) sends out rays in all directions, some rays from every point on the side next the eye will fall upon the cornea between E and F, and by passing on through the humours and pupil of the eye, they will be converged to as many points in the retina, or bottom of the eye, and will thereon form a distinct inverted picture c, b, a, of the object. Thus the pencil of rays q, r, s, that flows from the point A, of the object, will be converged to the point a on the retina; those from the point B, will be converged to the point b; those from the point C will be

* Encyclopædia Britannica.

converged to the point c; and so of all the intermediate points; by which means the whole image a, b, c, is formed, and the object made visible."

It is universally acknowledged that the Almighty has created nothing in vain, therefore the cornea must have been created convex, and of greater convexity than any other part of the eye to produce some effect in the phenomenon of vision; this is incontrovertibly proved by what takes place, when by age, or injury, its convexity has been lessened, which is, that near vision becomes indistinct, and can only be made distinct by the use of convex glasses, which, widening the angle of the rays of light before they touch upon the cornea, enables its remaining convexity to converge them to the central point as between the cornea and the chrystalline humour; no effect, however, has been ascribed to it.

In the figure, which is borne out by the foregoing explanation, it is evident that it is necessary to make the pupil much larger than, under ordinary circumstances, it is ever found.

The effect likewise represented to be produced by the chrystalline humour, is completely at variance with the well-known effects of convex lenses (for the chrystalline humour is neither more nor less than a double convex lens in the eye, which, there is as little doubt, produces the same effects), for, instead of converging the rays

of light in one cone, from the inverted image of the object delivered upon the front side of the chrystalline humour, to the conjoint radius (or focus) of its convexities (whence they diverge again at the same angle and to an equal distance to the retina, where they deliver the image of the object upright) it is made to take up the rays from where they are delivered upon it, and carry them in as many pencils or cones to the retina, as there are points in the object.

It is admitted that confused vision is produced by squinting, and that consequently, a person so afflicted, is frequently compelled to look at objects with one eye only, so as to have a correct view of them; this, no doubt, is the case, and is occasioned by rays being carried from different points in the objects to one and the same point in the sensorium; each eye having at the same time, a correct image of the object upon its retina, but differing in situation.

If this, therefore, is the case, is it not reasonable to conclude that a like confusion would be produced if the rays entered the eye, from an object, in the manner represented, for rays from AB and C are made to touch the chrystalline humour in the very same points?

Further, if the rays proceeded from such an object as ABC, which, it is evident, from its size, is not calculated, according to our experience, to prevent our seeing other objects which might be before us, entered the pupil in the

manner represented, i. e. occupying the entire diameter of the pupil, what confusion would not take place, upon the rays from those other objects entering the eye, and which, our experience teaches us we could, at the same time, see?

I am therefore of opinion, that the rays entering the eye, from different objects, differently situated before it, enter it as distinct and unmixed with each other, as the objects themselves are.

I shall now endeavour to investigate the cause that could have led to the error of supposing the images of objects to be delivered at the foci of pencils of rays light.

It is stated in the Rev. Dr. Blair's Grammar of Natural and Experimental Philosophy, as follows:

"161. If parallel rays fall upon a plano-convex lens, they will be so refracted as to unite in a point behind, called the principal focus, or focus of parallel rays.

"Exam.: Thus the parallel rays a a b b, (fig. 37.) falling upon the lens c d, are refracted towards the perpendicular C x, and unite in a focus C.

"162. The distance from the middle of the glass to the focus, is called the focal distance; which focal distance in a plano-convex lens is equal to the diameter of the sphere of which the lens is a portion (fig. 37.) and

the focal distance of a double convex lens is equal to the radius of a sphere of which the convexity of the lens is a portion (fig. 41.)

" 163. All the parallel rays of the sun which pass through a convex lens as DE, or c a, are collected in its focus f or C, and the force of the heat at the focus is to the common heat of the sun, as the area of the glass is to the area of the focus.

" Illust. : If a lens four inches in diameter collect the sun's rays into a focus at the distance of twelve inches, *the image will not be more than one-tenth of an inch in diameter*; the surface of this little circle is 1600 times less than the surface of the lens, and consequently the heat will be 1600 times greater at the focus than at the lens.

" In illustration 4, of 164, it is advanced '*Where the rays meet, they will form an inverted image of the flame of the candle.*' "

From the foregoing extracts, and figures in illustration, it is evidently considered that the images of objects are delivered at and by the foci of glasses. I presume to think, however, that this is incorrect; and shall endeavour to explain why I think so.

Take a plano-convex lens into a dark room into which the reflected light is admitted by a door or window, and let the inverted image of an object opposite, on the outside, be produced upon a piece of paper held behind the lens—and

let another person measure the distance between the lens and the paper; then present the lens to the direct rays of light from the sun, and refract them to their focus—i. e. to their point of concentration, and then measure the distance between the lens and the paper; it will then be found that the distances between the lens and paper will, in both cases, be the same.

Then take the same lens and refract the direct light from the sun into a Camera Obscura upon a door, or any other object calculated to receive it, in order to obtain an inverted image of it; then measure the distance between the lens, (which should be placed in the hole of the Camera Obscura) and the image of the sun, and you will find that that image is not at the focal distance of the direct light, but at twice that distance.

To illustrate this, let a, a, b b (fig. 17.) be rays from the sun refracted by the plano-convex lens e d; their focus will be at C, at the distance of the diameter of the circle of which the convexity of the lens forms a portion; but the image of the sun will not be delivered there, but at e, at an equal distance, on the opposite side, from the focus, as the lens is from it, where the rays diverge to, after having crossed at the focus, and where only they will deliver a distinct image; this image will be a great deal larger than the tenth of an inch, the size supposed to be delivered at the focus.

It naturally follows, if the distinct image of the sun can only be produced in this way, that the images of other objects, produced in a Camera Obscura by the refraction of reflected light by the same lens, must be produced in a similar manner. But if the images of objects are produced in a dark room (not a Camera Obscura), into which light is admitted at a door or window, upon paper, by a convex lens, they are not produced, I presume to think, in the same way as above explained, but by rays of light proceeding, from the inverted images of objects upon the front side of the lens, through the lens, in the same manner as represented respecting concave glasses, diverging as from the focus of its convexity before it, and, after passing out of the lens, continuing to diverge in the same angle to the focal distance behind it, where they deliver the images inverted, and much magnified; I have been led to this idea, in consequence of finding the images of objects, thus produced, so much larger than the lens, and that they diminish in size in that exact progressive manner, as the lens is brought nearer the paper,

To illustrate this, let AB (fig. 18.) be an object; C the lens with the inverted image upon its front surface; E rays diverging as if they had crossed at the focal distance of the lens before it, and proceeding, through the lens, to the focal distance behind it, where they deliver a beautiful in-

verted image of the object upon a piece of paper, but greatly magnified, as D. In this experiment, may it not be reasonably conceived that, to produce this inverted image, the rays from the object must cross before they arrive at the lens; and, may it not be equally reasonable to conceive, that those rays cross at the focal distance, as that is the only distance at which distinct images of objects are produced by lenses? I am in hopes this may be conceded, when the inverted image on the front of, and the effect produced behind the lens, are duly considered.

It would appear, therefore, that, in the Camera Obscura, the images of objects are not delivered at the foci of glasses, but at twice the focal distance, and not by points of concentrations of pencils of light, but by the divergent rays, after having crossed at their foci; it would likewise appear that the images of objects produced in a dark room (not a Camera Obscura) are produced at the focal distance from the lens, by the rays diverging as from the focal distance before the lens, to the focal distance behind it.

May it not, therefore, be reasonably inferred, that the error of supposing that the inverse images of objects, refracted by convex glasses, are produced at and by the foci of as many pencils of rays of light, as there are points in the object, has taken its rise from the misconceptions above explained? viz.

1st. From the idea that images of objects are

produced at and by the foci of various pencils of rays of light refracted by one and the same lens, probably arising from the circumstance of the distance at which they are produced, being the same.

2dly. From the consequent conclusion that, as the images, supposed to be produced there, are not of greater diameter than the tenth of an inch, it must require as many foci of pencils of rays of light as there are points in the objects, to produce such extended images as are produced by lenses.

I shall now proceed to the explanation of my Theory, which I establish upon

THE ANALOGY OF THE CAMERA OBSCURA.

It has justly been considered ever since the time of Maurolycus, that vision is produced by the same principle which produces the Camera Obscura; of this, the least doubt cannot, for a moment, exist, although the manner in which it is effected has not hitherto been suspected; this, therefore, I shall now endeavour to explain.

Let A (fig. 10.) be a room, darkened so as to admit light only at one hole, let the space between the lines b b, be the hole, low enough that the experiments can be made with ease opposite to it inside the room; then let a person hold a piece of white paper opposite the hole, and near it, and withdraw it gradually until he sees the objects on the outside of the room represented upon it, which will be the case as at B, and very beauti-

fully, but reversed in every part, i. e. if a house, the roof will be down, and the ground, &c. up, what is really on the right hand will be represented on the left, and, vice versa, in every the most minute parts.

Now the cause of this seems to be, that, of the rays which are reflected from objects in every direction, those only which enter the hole perpendicular to its outer surface, did it constitute the segment of a circle, (by proceeding to the centre of its convexity, inside the room, and after crossing there,* diverging again at the same angle in which they converged, until they arrive at the focus of its convexity,) convey the image to, and deliver it upon, the paper; the consequence of this, it is evident, must be, that the objects are represented inverted in every part.

Having long known, in consequence of having made experiments on the effects produced by the Camera Obscura, that a convex lens, used instead of the paper, (as in the foregoing illustration) to receive the inverted image at the first focus, produces the image of the objects upon the paper, held behind

* I have some idea that the rays, instead of crossing at the radius of the convexity of the lens, as above explained, may cross at the focal distance; but, as I have neither had time nor opportunity to make experiments, so as to ascertain the fact, I am inclined to leave this to some future period, rather than delay publishing the principle which seems borne out in so many ways.

it, upright,* I immediately saw, on becoming acquainted with the internal structure of the eye, that it was nothing more or less than a Camera Obscura, and that vision was produced in exactly the same manner as the above experiment points out.

To illustrate this, instead of the paper, let a plano-convex lens be held at B (fig. 19.) to receive the inverted image at the first focus, and let another person hold a paper behind the lens, and withdraw it back until the image of the objects appear upon it, and it will be found that every part will be seen in its proper place and upright as they appear to the eye, as at C.

I shall now apply the foregoing principle of the Camera Obscura to the eye. Therefore, let AB (fig. 20.) be the object presented to the eye; CD the rays of light proceeding from the object in every direction; E those rays which proceed to the cornea perpendicularly to its convexity, and convey the image of the object; G the centre of convexity of the cornea; H the chrystalline humour (or double convex lens of the eye) upon which the rays diverge from the centre of convexity of the cornea: I, the conjugate centre of the double convexity of the chrystalline humour, in the centre of the vitreous humour, where the rays are converged by its double convexity, and whence they diverge upon the re-

* I frequently made these experiments, for amusement, when about 17 years of age.

tina, in exactly the same angle in which they were converged; .K the image of the object upright upon the retina, at an equal distance from the conjugate focus, as that of the lens from it, with all its parts in their natural situations as they are seen by the eye.

Although the analogy betwixt the Camera Obscura and the eye is thus made evident, the following explanation of their phenomena will render it still more conclusive if possible.

It will be found, on making experiments with the Camera Obscura, that, when a cloud obscures the light of the sun, the images of objects, which were before bright and beautiful, become scarcely discernible; now, it is well known that, when a person goes out of a bright glare of light, into more moderate light, he loses, or has a very imperfect sight of the objects he before saw distinctly; this, therefore, is the very same effect produced on vision, as that above mentioned on the Camera Obscura, and by the very same cause, i. e. the want of sufficient light to produce the effect; the only differences that seem to exist are, that the muscularity of the uvea enables it to expand the pupil so as to admit a sufficiency of light to produce the effect, which cannot take place in the hole of the Camera Obscura (which represents the pupil) through which the light enters, and that there is no plano-convex lens before the hole to pro-

duce the effect of the cornea and its aqueous humour.

A similar effect is produced on vision when a person goes out of a moderate, into a glare of light, i. e. he loses, or has but a very imperfect sight of the objects before him, which he saw very distinctly before ; the cause of this is, that the pupil, having expanded in the moderate light so as to admit a sufficiency of light into the inner chamber of the eye to produce vision, admits too much light in the glare, which, illuminating the inner chamber of the eye, destroys, the Camera Obscura.

This loss or imperfection of vision, however, produced by the above causes, is but of very short duration, for the uvea very soon expands the pupil, in the first case, the stimulus of the glare of light having decreased, and, in the second case, as soon contracts it, so as to accommodate it to the production of vision. I have no doubt, therefore, should the hole of a Camera Obscura be constructed in such a manner as to admit of contraction and expansion, and a plano-convex chrystalline lens placed before it, to produce the effects of the cornea and its humour, the very same effects could be produced upon it.

I am led to conclude, that the rays of light which convey the images of objects to the Camera Obscura, are those which are perpendicular to the convexity of the hole, as a segment of

a circle, for this reason, that the limits of the objects visible are exactly where, a right line proceeding from the radius, past the edge of the hole, would touch; I am likewise of opinion, that the rays, which produce vision, are those which proceed from the objects to the cornea perpendicular to its convexity.

1st. Because it is evident we see almost all objects within the arc of the segment of the cornea, in their exact relative proportions and situations; even so close to the edge of the cornea do the rays of light enter, that it almost appears as if they were parallel to the uvea, through the centre of which, at the pupil, they enter into the inner chamber of the eye; this, therefore, could not be the case, unless the rays enter the eye perpendicular to the convexity of the cornea; in fact, was there no other evidence to invalidate the idea that the aqueous humour has an innate refractive quality, independent of the convexity of its surface, this would give rise to the idea that it did not, at all events, operate in the production of vision, for it is evident, as the rays enter all round the arc of the cornea, conveying the images of the objects whence they are reflected, that there cannot be any room left to admit of their direction being changed.*

* This seems to suggest that the cornea must nearly constitute a semicircle, and that its radius must be very nearly, if not exactly, in the centre of the pupil: In fact, it seems there is only one evidence more to be brought forward to render this Theory reasonable, which is, that if the rays of light

2dly. If the rays did not enter the cornea perpendicular to its convexity, and was not that convexity accessary to the production of vision, why do we lose perfect vision of near objects when that convexity has become lessened from age, or great exertion of the organ, and why is this defect remedied by convex glasses? The fact seems not to be doubted, therefore, that the convexity of the cornea forms the primary agent in the production of vision, and that the rays which produce vision enter the eye perpendicular to that convexity, for the eye, whose cornea is very prominent, has indistinct vision of distant, as that which has become less convex, has indistinct vision of near, objects; the too prominent eye converges the rays, which are perpendicular to its convexity, to a radius nearer the cornea than the chrystalline humour, consequently the focus of that convexity is not at such a distance as the chrystalline humour, at least for distant objects; the lessened convexity converges the rays, which are perpendicular to its then convexity, to the radius of that convexity, which is nearer the chrystalline humour than the cornea, therefore, the focus is farther

did not cross nearly in the pupil, how could we possibly have such an extensive arc of vision when we are exposed to a glare of light when the pupil of the eye is not larger than the head of a small pin, and how could that arc be equally extensive then, as when we are in a moderate light, and the pupil consequently much dilated?

off than the front side of the chrystalline humour for near objects, consequently indistinct vision arises; the reason why convex spectacles in the last, and concave in the former, case remedy the defects is, because the former widen the angle of the rays, and the latter make it narrower, which enable the convexities of the corneas to converge the cones of rays to radii equidistant between their respective corneas and chrystalline humours.

This concurrense is a wonderful provision of the Almighty wisdom, which prevents any great exertion of the cornea to converge the rays of light; the effect of the contrary is well known to those whose near vision has failed from causes already mentioned; for, as all glasses, which remedy the defect, enlarge the angle of the rays, the exertion of the cornea to complete the concentration produces a stiffness, and sometimes pain, if not inflammation,* from the long continued use of them at one time.

Was I not convinced, by the figures illustrative of his doctrine, as well as his silence as to this theory of vision, which, if he had been aware of, being a new principle, most certainly would

* On the very day I wrote the above, having had occasion to see a young lad who was labouring under an inflammation in one of his eyes, I was informed that it had been produced by the use of a high magnifying glass, used by watchmakers, (which business he was learning.) He has recovered from the effects, but has been compelled to desist from persevering in that business.

not have escaped such an ingenious and learned man, I should almost have conceived Dr. Chas. Bell had been aware of it, from the following passage on the subject in his Anatomy: "accordingly when the coats are cut from the back, the picture of a luminous object, held before the pupil, is seen exquisitely minute, and distinct on the bottom of the eye;" but his plates represent the object upon the retina inverted, at the same time that the other parts of the figure do not differ, in scarcely any respect, from the present received doctrine upon the subject already quoted.

It is the received doctrine that, when the coats are cut from the back of the eye, the image of an object, before it, is delivered upon a piece of white paper, placed over the orifice, inverted, by the agency of the Camera Obscura of the eye.

I am decidedly of opinion, however, that, if the image does appear upon the paper inverted, it is not produced by the Camera Obscura, and I conclude so from this circumstance, that, if the coats are taken off from the back of the eye, the transparency thereby produced would admit the light into the inner chamber of the eye, and destroy the Camera Obscura as affecting the retina, and obliterate the image of the object which existed there before; and even that this must be the case if a piece of white paper is placed upon the orifice, so that the image of the

object may be delivered upon it, for the same light, admitted by the paper, and which enables a person to see the image of the object, so delivered upon it, would prevent the effect of the Camera Obscura.

I am, therefore, of opinion, that the inverted image of the object, seen upon the paper, was nothing more than the reflection of the inverted image of it produced, upon the front side of the chrystalline humour, by the Camera Obscura, the light admitted at the back not having destroyed the Camera Obscura in the forepart of the inner chamber of the eye.

Although I have been all along satisfied of the correctness of this theory, by which, I conceive, vision is produced, yet I have lost no opportunity of obtaining information on the subject. I have, therefore, consulted several eminent Physicians and Surgeons, who have informed me that the chrystalline humour is frequently cut out of the eye in order to give vision, and that in some cases vision is as perfectly restored as before it was injured or lost, and in others only imperfectly.

Dr. Bland, Surgeon of his Majesty's ship Pyramus, has informed me, that a person who was Janitor of the College of Glasgow, where he studied, had had the chrystalline humours cut out of both eyes, for the purpose of giving him vision, and that he could, afterwards, (at the period he was there) see as perfectly as before he lost his sight.

These cases, had I not been satisfied of the correctness of my theory, were calculated to make it appear, that the chrystalline humour contributes very little to the production of vision, however, were all evidence and experiments apparently against me, I should still think I was correct, for I cannot be mistaken in my principle, grounded as it is upon the closest analogy betwixt the Camera Obscura and the eye.

Seeking information, however, from every source, whence it was likely to be obtained, I recollected that a person of this City, of the name of M. K. Schaw, had submitted one of his eyes, which he had lost the sight of, in consequence of having received a kick upon the temple from a horse, to my inspection, informing me at the same time, that a Surgeon had given it as his opinion that he had lost the sight of it in consequence of the chrystalline humour having been thrown out of its capsule by the shock, I made inquiries respecting him, in order to have a full explanation of his case from himself; he informed me, that, for some time after he received the kick, he could not see in the least, with the eye, but that afterwards he gradually recovered the sight of it, but all objects appeared inverted, and hazy and indistinct, but that he now sees them upright, and as distinct as ever he did.

The above case tends very much to confirm my theory, and, I am of opinion, may lead to some light being thrown upon Surgery.

According to this Theory, if the chrystalline humour is lost out of the eye, the very same effects ensue, that Mr. Schaw explains he was sensible of, when he first found his sight was returning, which is, that objects will appear hazy and indistinct, and, at the same time, inverted; this is occasioned by the rays, (as the chrystalline humour is not in its place to obstruct them, and receive the inverted image of the objects) after they have crossed at the radius of the convexity of the cornea, proceeding on to the retina, upon which they deliver the image of the object inverted and indistinct; this indistinctness is in consequence of the rays having proceeded so far beyond the focus of the convexity of the cornea (where alone the distinct image is delivered) before they met any object capable of receiving the image.

In illustration, let A (fig. 21.) be the radius of the convexity of the cornea; B the rays proceeding on uninterruptedly to the retina, where they deliver an indistinct and inverted image as E; it is evident, that the image will be much larger than it is in a perfect eye; to be convinced of which, it is only necessary to compare this figure with that of the perfect eye (fig. 20).

The circumstance, above mentioned, of Mr. Schaw's recovery of perfect vision threw me back upon my principle, but with unabated confidence, to inquire into the cause which could have produced it; during my reflections, which

did not occupy five minutes. I coupled the case mentioned by Mr. Bland with it, when I became convinced that, in Mr. Bland's case the chrystaline humour had, and in Mr. Schaw's has, been regenerated.

Now, in order to render this idea probable, it is only necessary to observe, that it is well known to the profession that, when the cornea has, by accident, or otherwise, lost part of the aqueous humour which distends it, it is regenerated in the short space of 24 hours; if, therefore, one humour is regenerated, is it not probable that another may be, particularly when we reflect upon the evidence above adduced leading so strongly to that conclusion?*

* My communications with Professional Gentlemen have brought a remarkable corroborative circumstance to my knowledge: this is, that all those who undergo the operation for cataract, recover upright vision immediately, upon the diseased lens being extracted, although not distinct; whether it can be considered in favour of this theory that we can readily trace from effects to causes, I shall not decide, but it seems very easy to account for this phenomenon, which has been hitherto completely enveloped in impenetrable mystery; it has been shewn, that if there was no lens, after the diseased one has been extracted, to receive the inverted image of the object, the rays would proceed on from the radius of the convexity of the cornea to the retina, and there deliver the image inverted; this being the case, does not the circumstance of their being seen upright suggest, that a new lens had been partially regenerated behind the diseased one? To remedy this imperfection of vision it is necessary, at first, to use highly convex glasses, but progressively, afterwards, those of less convexity, until, as in some cases, as has been shewn, its complete restoration has been effected; these circumstances have led me to in-

After having gone thus far, I conceived it would be unpardonable to allow such a strong evidence against this theory, as the experiment upon the bullock's eye, to remain uninvestigated, whether the inverted image upon the paper was really the effect of the Camera Obscura, or the reflection of the inverted image upon the front surface of the chrystalline humour: Therefore, on the 30th May last, very early in the morning, I obtained a fresh bullock's eye, and, having cut off the coats from the back of it, just where the optic nerve entered it, (where the region of most perfect vision is situated) I presented the front of it to a lighted candle, when I saw the image of the flame and top of the candle inverted, upon a piece of white paper I had placed

quire into the causes productive of the above phenomenon; the causes seem to be, that the loss of the aqueous humour, consequent to the operation, may not have been recovered in the same quantity as before, so as to distend the cornea to the necessary convexity, at the same time that the new lens cannot have acquired its proper convexity, owing to part of the necessary space having been previously occupied by the diseased one; may not, therefore, the progressive improvement in some, and complete restoration in others, be reasonably attributed to the more or less perfect regeneration of those humours? In Mr. Schaw's case, might not the entire loss of vision, at first, have been occasioned by a paralization of the optic nerve, and might not that have produced a paralization of the secreting vessels, and thereby prevented the previous regeneration of the lens, (the want of which occasioned the objects being seen inverted,) and might not its subsequent gradual reproduction have produced the changes which took place until the objects were seen upright?

over the orifice; the report, therefore, of the effect of the experiment, before made in this way, proved to be correct; after this, having taken the paper off the orifice on the back of the eye, I looked into it, still holding the front opposite the candle, and to my astonishment saw (for, although I firmly believed it was the case, yet I did not expect it could have been seen) in the inside of the eye, the same inverted image of the candle and flame I before saw on the paper, but more distinct.

There is, therefore, no doubt, that the inverted image, seen on the paper on the back of the eye, was nothing more than the reflection of the inverted image of the object, produced upon the front side of the chrystalline humour, by the Camera Obscura.

THE END.

Fig 1

ERRATA.

Page 25, third line, for "less" read "**more.**"
—— 26, second paragraph, first line, for "point" read "part."
—— 26, third paragraph, tenth line, dele the word "that."
—— 27, second paragraph, third line, for "fig. 4" read "fig. 6."
—— 29, first paragraph, second line, instead of "by" read "with."
—— 36, dele note.
—— 43, In note, eighth line, instead of "*a*ffected" read "*e*ffected."
—— 59, fourth paragraph, first line, instead of "fig. 10" read "fig. 19."

Explanation how the caloric, which prevails near our Globe, may be produced.

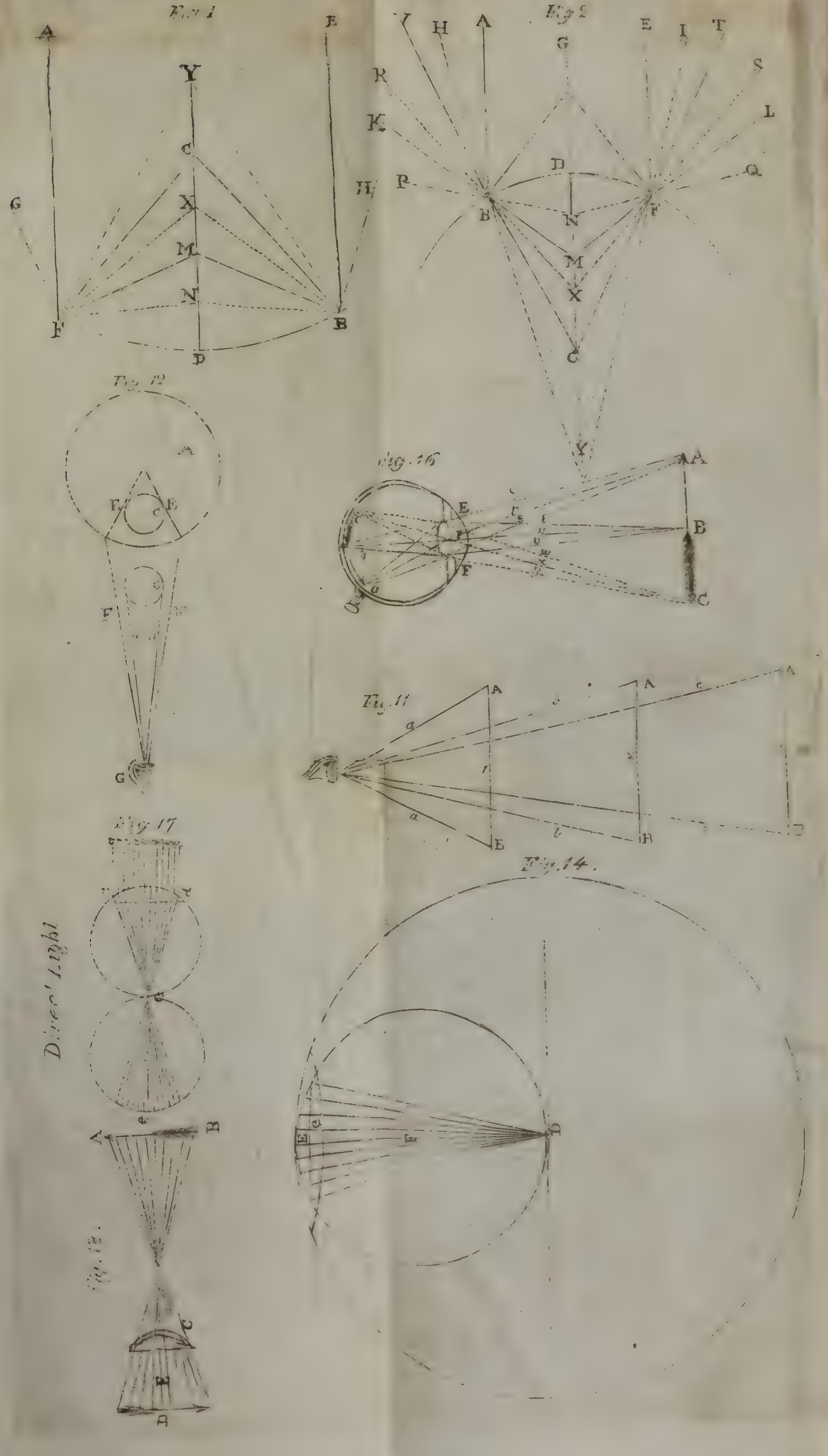


Fig. 1
Fig. 2
Fig. 12
Fig. 16
Fig. 11
Fig. 17
Fig. 13
Fig. 14
Direct Light

Fig 2

Fig. 3

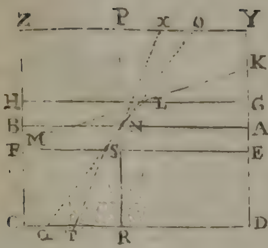


Fig. 4

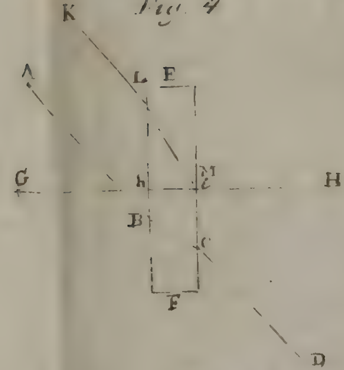


Fig. 7

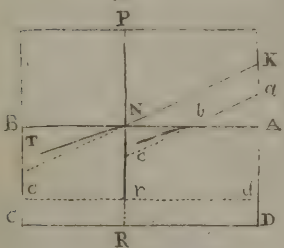


Fig. 6

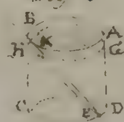


Fig. 5

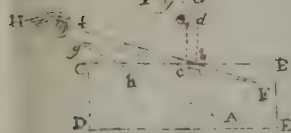


Fig. 10

Fig. 9

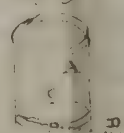


Fig. 8

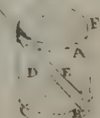


Fig. 15

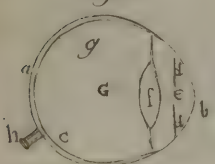


Fig. 13

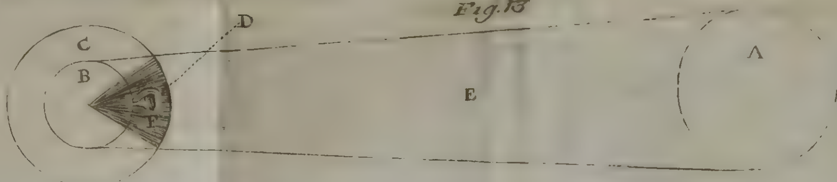


Fig. 37

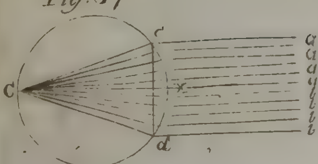


Fig. 19

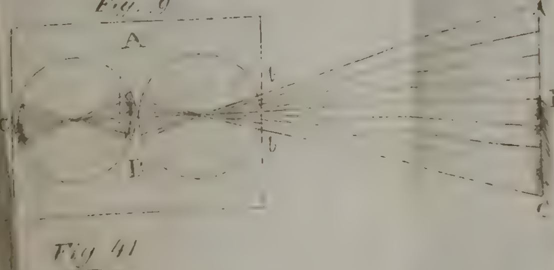


Fig. 20

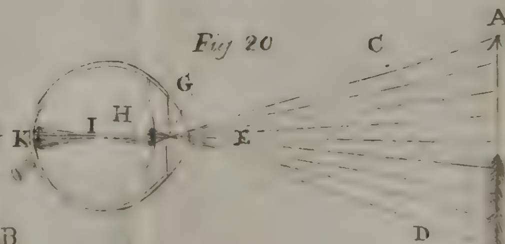


Fig.

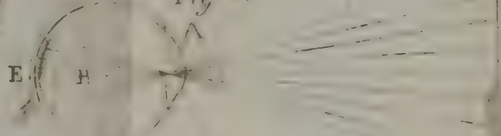
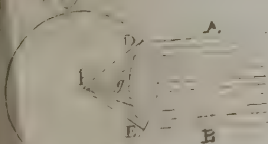


Fig. 41



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